

3.0 AREA OF REVIEW 2016 ADDENDUM

Any new wells drilled or plugged since the 2009 Petition submittal would (through regulatory requirements) meet construction standards (for drilled wells) or the necessary weight mud (plugged wells) to prevent endangerment of USDWs or migration of hazardous constituents out of the Ineos Injection Zone due to facility operations. A December 2015 review of the AOR indicates that no new wells penetrating the Injection Zone have been drilled or plugged since the 2009 Petition submission.

No new Class II injection wells that penetrate the Injection Zone have been drilled within the 2.0-mile composite radius AOR or modeled plume areas since 2009. As noted in the 2009 submittal, a Class II injection well within the 2-mile radius AOR (Map ID No. 70) injects at a low rate (less than 3 gpm) into a thin sand stringer not in communication with the WDW-163 Injection Interval, while a Class II injection well within the 10,000 year plume (Map ID No. 27) injected into strata above the WDW-163 Injection Interval but is now shut in.

6WQ-SG

FEB 11 2016

MAY - 6 2009

3.0 AREA OF REVIEW

In accordance with the requirements for the Area of Review (AOR) found in 40 CFR §148.20(a)(2)(i) and 40 CFR §148.20(a)(2)(ii), Ineos has: (1) determined the Petitioned injection wells composite AOR in accordance with the requirements of 40 CFR §146.63; and, (2) located, identified, and ascertained the condition of all wells within the injection wells' determined composite AOR that penetrate the Injection Zone by use of an acceptable protocol in accordance with the requirements of 40 CFR §146.64.

The artificial penetrations within the Ineos composite AOR for this no-migration Petition re-issuance application must meet one or both of two criteria: artificial penetrations within the cone of influence (defined in Section 3.1 below) must meet the non-endangerment standard; artificial penetrations within the boundaries of the operational/10,000-year waste plumes must meet the no-migration standard; and artificial penetrations within the cone of influence (COI) and within the boundaries of the operational/10,000-year waste plumes must meet both the non-endangerment and no-migration standard. To meet the non-endangerment (cone of influence) standard, a well penetrating the Injection Interval must be adequately completed and/or plugged with sufficient weight drilling mud/brine, cement plugs, or casing to prevent the movement of fluids upward out of the Injection Zone through the wellbore to a point of contact with a USDW. In order to meet the no-migration criteria, a well penetrating the Injection Interval must be adequately completed and, if plugged, the borehole should be filled with drilling mud, casing or cement plugs to prevent movement of hazardous waste constituents out of the Injection Zone at levels above the Land Ban health-based limits. The primary purpose of an AOR study is to verify that ground water resources are protected from contamination by formation brines or injectate fluids. For regulatory purposes, ground water resources are commonly referred to as underground sources of drinking water or USDWs.

The following sections address the manner in which Ineos has defined the area of review and presents, consistent with USEPA requirements, a discussion of the completion and plugging status of non-freshwater artificial penetrations located within the AOR and operational/10,000-year plumes for the three Injection Intervals, together with a discussion of the protocol used to locate and determine the status of these wells. In addition, a tabulation and a location map of fresh water artificial penetrations (water wells) within the AOR are included.

3.1 Determination of Area of Review

Two methods are available to determine the applicable AOR for a particular injection well. In accordance with 40 CFR §148.20(a)(2)(i) and 40 CFR §146.63, the AOR for a Class I hazardous waste injection well shall be either: (a) a 2-mile radius around the wellbore (fixed); or (b) the cone of influence (calculated), whichever is larger.

3.1.1 Calculated Area of Review

In accordance with 40 CFR §148.20 (a) (2) (i) and 40 CFR §146.63, the calculated AOR is determined by deriving the calculated cone of influence around the injection wellbore. The cone of influence is defined in 40 CFR §146.61 (b) to be "the area around the well within which increased Injection Zone pressures caused by injection into the hazardous waste injection well would be sufficient to drive fluids into an underground source of drinking water (USDW)." A determination of the cone of influence requires that pressure increases within each Injection Interval be determined using a reservoir pressure increase model. SWIFT pressure models were used to determine the Ineos pressure buildups and cones of influence within each Injection Interval for this Petition re-issuance application.

Pressure Modeling

The SWIFT model was used to simulate a projected ten-year operational injection period for each of the operating Ineos wells, each injecting into its respective Injection Interval at their maximum rates of 500 gpm each. Historical volumes injected into each interval were also included in that Injection Interval model. Each interval was modeled separately

as there is no interference between the three reservoirs due to their vertical separation. The models were used to estimate pressure increases after a ten-year future period of continuous injection well operations. The flexibility of SWIFT was used to incorporate variable fluid properties with depth and site-specific geology. A complete discussion of the SWIFT pressure modeling is given in Section 7.0 of this document.

In order to estimate pressure increases in the three Injection Intervals, each Frio Injection Interval was assigned representative depths, thicknesses, porosity, and isothermal compressibility. Variable thickness was assigned to each Injection Interval over the area of the model grid, based on geologic mapping. The native formation brine densities and viscosities, which are functions of depth, static bottom-hole temperature, brine salinity and brine compressibility, were employed in the SWIFT pressure models. The model input parameters for each of the Injection Intervals are shown in the SWIFT model input parameters tables (Tables 7-2a, 7-2b, and 7-2c). Site specific data were used, when available, to derive the model input parameters for the three Injection Interval pressure models.

The pressure buildups were modeled with the Ineos wells injecting into their appropriate Frio Injection Interval using the minimum model permeabilities, as noted in Tables 7-2a through 7-2c. These permeability values are conservatively lower than those measured during historical fall-off tests of the Ineos injection wells. Maximum injection rates of 500 gpm into each well were used in the SWIFT input files to simulate future injection into the three petitioned wells for a future ten-year period of continuous operation. These rates were selected based on optimum plant disposal requirements and maximum permit conditions. In addition, historical yearly averages rates in the Ineos injection wells were used to simulate the reservoir pressure increases during the petitioned wells' historical operational periods. These are conservative assumptions that maximize the pressure buildups in the SWIFT models.

Figure 3-1 is a plot of the maximum-modeled pressure increase in the WDW-163 reservoir around that well at the end of a ten-year future operational period. At the location of WDW-163, the Injection Interval reservoir pressure is calculated to increase a maximum of 253 psi, and 27 psi at a distance of two miles from that injection well after ten years of continuous future injection operations. Figure 3-2 is a plot of the maximum-modeled pressure increase in the WDW-164 reservoir around that well at the end of a ten-year future operational period. At the location of WDW-164, the Injection Interval reservoir pressure is calculated to increase a maximum of 767 psi, and 20 psi at a distance of two miles from that injection well after ten years of continuous future injection operations. Figure 3-3 is a plot of the maximum-modeled pressure increase in the WDW-165 reservoir around that well at the end of a ten-year future operational period. At the location of WDW-165, the Injection Interval reservoir pressure is calculated to increase a maximum of 615 psi, and 15 psi at a distance of two miles from that injection well after ten years of continuous future injection operations.

The pressure models are conservative since the upper and lower aquifer limits are modeled as no-flow boundaries and thus do not allow pressure dissipation vertically. Permeabilities of 500 mD (WDW-163), 40 mD (WDW-164), and 33 mD (WDW-165) were used. The lowest fall-off test permeabilities from those Ineos injection wells (see Table 7-5) are 596 mD, 89 mD, and 36 mD respectively. Using the lower permeabilities result in more conservative (higher) pressure increases in the models. For the ten-year future model simulation periods, the injection rates for the three wells were assumed to be continuous rates of 500 gpm each. In reality, these wells will not operate continuously and will have periodic shutdowns for maintenance and testing. Therefore, the actual measured flowing bottom-hole pressures will be lower than those modeled during the ten-year future injection periods.

Cone of Influence

The cone of influence is considered for the purposes of this application as that area surrounding each injection well within which increased pressures at the top of that Ineos

Injection Interval are sufficient to displace a mud or weighted fluid column in a non-freshwater artificial penetration wellbore that penetrates that Injection Interval such that fluids would be driven into a USDW. That wellbore is considered for this application to contain a 9.0 lb/gal fluid column extending from the top of the Injection Interval reservoir to a level 50 feet below the ground surface. A minimum uniform depth to the top of each reservoir is used in order to conservatively delineate the area of each Injection Interval's cone of influence.

Calculation of the cone of influence requires a determination of the reservoir pressure increase that would displace a mud or weighted fluid column in a wellbore penetrating the Injection Interval. Drilling mud in an abandoned wellbore is a barrier to vertical migration of native or injected fluids from the Injection Interval because of 1) the hydrostatic pressure differential between the mud column and the Injection Interval reservoir pressure, and 2) gel strength. One purpose of drilling mud is to control or overcome the formation pressures of the geologic stratum penetrated. To accomplish this, the hydrostatic gradient of the mud column must be equal to or greater than the formation pressure encountered. To determine the pressure or gradient exerted by a column of mud, a reported or estimated value of the mud weight in the wellbore is required. A review of available data indicates a range of mud weights were used for drilling and plugging wells within the vicinity of the Ineos wells. The lowest mud weight recorded as being used in the Ineos AOR was 9.5 lb/gal. The USEPA has accepted the use of a minimum 9.0 lb/gal mud weight in cases where plugging records indicate that drilling mud was used but no specific mud weight was listed. The pressure gradient increases in direct proportion with the weight of the fluid. A mud weight of 9.0 lb/gal would result in a pressure gradient of approximately 0.468 psi/foot of depth.

In addition to the mud hydrostatic head to be overcome, a hydrologic barrier related to the strength of the drilling mud must be overcome before fluid can move upward through a wellbore. When mud is allowed to remain quiescent for a period of time, a gel develops (Johnson and Knape, 1986). Until the structure of the mud gel is disrupted, the mud will

resist displacement. As reported by Barker (1981), drilling mud gel strengths can range from 25 to 120 pounds per 100 square feet. Assuming a low gel strength, a mud plug with a gel strength of 20 pounds per 100 square feet in a borehole with an average diameter of 12 inches should be capable of resisting a pressure of at least an additional 1) 29 psi $[(0.00333)(20)(5,302 \text{ ft})/12]$ for the WDW-163 Injection Interval, 2) 41 psi $[(0.00333)(20)(7,363 \text{ ft})/12]$ for the WDW-164 Injection Interval, and 3) 36 psi $[(0.00333)(20)(6,528 \text{ ft})/12]$ for the WDW-165 Injection Interval. Thus, the hydrostatic weight of the mud to be overcome and the strength of the mud gel yield a total pressure needed to initiate fluid movement into a mud-plugged borehole in the Ineos AOR.

Another mechanism which contains waste fluid in the Injection Zone at an abandoned well is borehole collapse. It is well documented that the geologically young and unconsolidated sediments of the Gulf Coast Basin tend to slough and swell, and that uncased wells in this region commonly squeeze shut within a matter of hours or days (Johnson and Knape, 1986; Clark and others, 1991). In order to be conservative, however, no borehole collapse was assumed for the abandoned boreholes within the Ineos AOR.

The top of the WDW-163 injection reservoir is at approximately 5,352 feet below ground level (BGL) at WDW-163. Using this reference depth of 5,352 feet for the top of the injection reservoir, the pressure exerted by a mud column of that height, less 50 feet of fallback, at a wellbore filled only with 9.0 ppg mud would be 2,481 psi $([5,352 \text{ ft} - 50 \text{ ft}] \times 0.468 \text{ psi/ft})$. Thus, the hydrostatic weight of the mud to be overcome (2,481 psi) and the strength of the mud gel (29 psi, see above paragraph) yield a total pressure needed of 2,510 psi to initiate fluid movement into a mud-plugged borehole open to the WDW-163 injection reservoir in the Ineos AOR. An initial bottom-hole pressure (BHP) of 2,270 psi at 5,622 feet BGL was measured in WDW-163 at the time of completion of the well. Converting that pressure to the injection reservoir top reference depth at 5,352 feet BGL using the native brine gradient of 0.451 psi/ft results in a pressure difference of 122 psi $([5,622 \text{ ft} - 5,352 \text{ ft}] \times 0.451 \text{ psi/ft})$, with the calculated initial static pressure at the top of

the injection reservoir being 2,148 psi. The formation pressure increase at 5,352 feet BGL would have to exceed 362 psi ($2,510 \text{ psi} - 2,148 \text{ psi}$) before any upward movement of reservoir fluids into a wellbore or upward out of the Injection Zone would be possible. Below this 362 psi injection reservoir pressure increase, there is no potential for movement of reservoir fluids into a wellbore, or vertically out of the Injection Zone due to increased injection pressures. This 362 psi pressure increase thus defines the limits of the area of the cone of influence around WDW-163. For purposes of this application, the cone of influence for the WDW-163 AOR is defined as that area around this Ineos petitioned injection well within which the modeled reservoir pressure increase due to injection operations exceeds 362 psi. This 362 psi pressure increase isobar conservatively defines the limits of the cone of influence within the WDW-163 Injection Interval across the composite AOR.

The top of the WDW-164 injection reservoir is at approximately 7,413 feet below ground level (BGL) at WDW-164. Using this reference depth of 7,413 feet for the top of the injection reservoir, the pressure exerted by a mud column of that height, less 50 feet of fallback, at a wellbore filled only with 9.0 ppg mud would be 3,446 psi ($[7,413 \text{ ft} - 50 \text{ ft}] \times 0.468 \text{ psi/ft}$). Thus, the hydrostatic weight of the mud to be overcome (3,446 psi) and the strength of the mud gel (41 psi, see above paragraph) yield a total pressure needed of 3,487 psi to initiate fluid movement into a mud-plugged borehole open to the WDW-164 injection reservoir in the Ineos AOR. An initial bottom-hole pressure (BHP) of 3,225 psi at 7,704 feet BGL was measured in WDW-164 at the time of completion of the well. Converting that pressure to the injection reservoir top reference depth at 7,413 feet BGL using the native brine gradient of 0.447 psi/ft results in a pressure difference of 130 psi ($[7,704 \text{ ft} - 7,413 \text{ ft}] \times 0.447 \text{ psi/ft}$), with the calculated initial static pressure at the top of the injection reservoir being 3,095 psi. The formation pressure increase at 7,413 feet BGL would have to exceed 392 psi ($3,487 \text{ psi} - 3,095 \text{ psi}$) before any upward movement of reservoir fluids into a wellbore or upward out of the Injection Zone would be possible. Below this 392 psi injection reservoir pressure increase, there is no potential for movement of reservoir fluids into a wellbore, or vertically out of the Injection Zone due

to increased injection pressures. This 392 psi pressure increase thus defines the limits of the area of the cone of influence around WDW-164. For purposes of this application, the cone of influence for the WDW-164 AOR is defined as that area around this Ineos petitioned injection well within which the modeled reservoir pressure increase due to injection operations exceeds 392 psi. This 392 psi pressure increase isobar conservatively defines the limits of the cone of influence within the WDW-164 Injection Interval across the composite AOR.

The top of the WDW-165 injection reservoir is at approximately 6,578 feet below ground level (BGL) at WDW-165. Using this reference depth of 6,578 feet for the top of the injection reservoir, the pressure exerted by a mud column of that height, less 50 feet of fallback, at a wellbore filled only with 9.0 ppg mud would be 3,055 psi $[(6,578 \text{ ft} - 50 \text{ ft}) \times 0.468 \text{ psi/ft}]$. Thus, the hydrostatic weight of the mud to be overcome (3,055 psi) and the strength of the mud gel (36 psi, see earlier paragraph) yield a total pressure needed of 3,091 psi to initiate fluid movement into a mud-plugged borehole open to the WDW-165 injection reservoir in the Ineos AOR. As no initial bottom-hole pressure (BHP) was measured in WDW-165, the initial BHP of 3,225 psi at 7,704 feet BGL as measured in WDW-164 was used to convert to the BHP at the top of the WDW-165 injection reservoir. Converting that pressure to the injection reservoir top reference depth at 6,578 feet BGL using the native brine gradient of 0.448 psi/ft results in a pressure difference of 504 psi $[(7,704 \text{ ft} - 6,578 \text{ ft}) \times 0.448 \text{ psi/ft}]$, with the calculated initial static pressure at the top of the injection reservoir being 2,721 psi. The formation pressure increase at 6,578 feet BGL would have to exceed 370 psi (3,091 psi - 2,721 psi) before any upward movement of reservoir fluids into a wellbore or upward out of the Injection Zone would be possible. Below this 370 psi Injection Interval reservoir pressure increase, there is no potential for movement of reservoir fluids into a wellbore, or vertically out of the Injection Zone due to increased injection pressures. This 370 psi pressure increase thus defines the limits of the area of the cone of influence around WDW-165. For purposes of this application, the cone of influence for the WDW-165 AOR is defined as that area around this Ineos petitioned injection well within which the modeled reservoir pressure increase due to

injection operations exceeds 370 psi. This 370 psi pressure increase isobar conservatively defines the limits of the cone of influence within the WDW-165 Injection Interval across the composite AOR.

The SWIFT numerical models (see Modeling Section 7.0 for a detailed discussion of the models and their input parameters) were used to calculate pressure increases that will occur in the three Injection Intervals at the end of a projected ten-year future injection timeframe at the Ineos injection wells. From the model outputs, the calculated cones of influence (pressure increases of 362 psi (WDW-163), 392 psi (WDW-164), and 370 psi (WDW-165) were determined.

Injection rates used in the models reflect historical yearly average rates since injection began (total historical period averaging 24 years for the three wells) and ten-year maximum future injection rates for each of the three Ineos wells. The results of the SWIFT numerical pressure models are shown graphically in Figure 3-4 and in tabular form in Table 3-1, denoting the future predicted flowing BHPs in the three Injection Intervals. This table and figure present the model predicted future flowing BHPs in the three Injection Intervals at the depths of each injection well's respective grid block center. These results indicate that after a total 10-year projected timeframe (end of injection 12/31/2017), the Injection Intervals' reservoir pressures are a maximum of 2,460 psi at WDW-163 (at a depth of 5,501 feet), 4,010 psi at WDW-164 (at a depth of 7,766 feet), and 3,610 psi at WDW-165 (at a depth of 7,214 feet). The pressure increase around the wells decreases radially from the Ineos injection wells as depicted on Figure 3-1 (WDW-163 Injection Interval), Figure 3-2 (WDW-164 Injection Interval), and Figure 3-3 (WDW-165 Injection Interval). Based on the maximum modeled Injection Zone reservoir pressure increases (Figures 3-1, 3-2, and 3-3), the pressure increases is not sufficient to generate cones of influence (pressure increases of: ≥ 365 psi—WDW-163 Injection Interval, ≥ 392 psi—WDW-164 Injection Interval, and ≥ 375 psi—WDW-165 Injection Interval) beyond maximum distances of approximately 0 feet (WDW-163 Injection Interval), 50 feet (WDW-164 Injection Interval), and 200 feet (WDW-165 Injection

Interval) from the Ineos injection wells. Therefore, pressure increases in the Ineos Injection Intervals will not be sufficient to potentially endanger the local USDW in an artificial penetration (which penetrates that Injection Interval) located beyond those distances from the Ineos injection wells.

Non-Endangerment Standards For Artificial Penetrations

In order to determine whether artificial penetrations within the composite AOR surrounding the Ineos wells meet standards so as to prevent endangerment of the USDW due to increased Injection Interval pressures, the calculated reservoir pressure increases were determined. The SWIFT models determined the effects of injection into the three intervals incorporating all historical and future injection, and predicted the maximum Injection Interval reservoir pressure increases that would be expected at artificial penetrations within the composite AOR. These expected reservoir pressures were then compared to a calculated reservoir pressure increase that would be required to displace a mud or a weighted fluid column in an abandoned wellbore such that fluids would be driven into a USDW. As noted in the previous paragraphs, the largest cone of influence was determined to not extend beyond 200 feet from the Ineos injection wells, and thus encompass no other artificial penetrations that penetrate the Ineos Injection Zone. Thus all of the artificial penetrations within the Ineos composite AOR and operational/10,000-year plumes beyond a distance of 200 feet meet the non-endangerment standards through the presence of at least a mud plug in the borehole.

The WDW-163 Injection Interval reservoir pressure is calculated to increase a maximum of 253 psi at that well and approximately 27 psi at a distance of two miles from the well at the modeled end of operation (12/31/2017) (see Figure 3-1). The Injection Interval reservoir pressure increase does not reach 365 psi (the determined cone of influence) at that well after 10 future years of continuous injection. The WDW-164 Injection Interval reservoir pressure is calculated to increase a maximum of 767 psi at that well and approximately 20 psi at a distance of two miles from the well at the modeled end of operation (12/31/2017) (see Figure 3-2). The Injection Interval reservoir pressure

increase does not reach 392 psi (the determined cone of influence) beyond 50 feet from that well after 10 future years of continuous injection. The WDW-165 Injection Interval reservoir pressure is calculated to increase a maximum of 615 psi at that well and approximately 15 psi at a distance of two miles from the well at the modeled end of operation (12/31/2017) (see Figure 3-3). The Injection Interval reservoir pressure increase does not reach 375 psi (the determined cone of influence) beyond 200 feet from the well after 10 future years of continuous injection. Within this largest cone of influence (WDW-165 Injection Interval), only the three operating Ineos injection wells are present. The Ineos wells have externally cemented casings from the tops of their respective Injection Intervals to the surface, and their annuluses are continuously monitored for mechanical integrity, thus providing no conduits for movement of fluid or pressure effects upward out of the Ineos Injection Intervals. These injection wells thus also meet non-endangerment standards. There appears to be no potential for movement of reservoir fluids into a wellbore or vertical movement of fluid from a wellbore into a USDW beyond the determined cones of influence due to pressure increases in the Injection Interval reservoirs as a result of Ineos injection well operations. Actual operations typically include shut down periods which allow for reservoir pressure recovery cycles that reduce the maximum build up pressures. In addition, it is very unlikely that Ineos will operate the injection wells at continuous, non-ceasing, maximum permitted injection rates.

No-Migration Standards for Artificial Penetrations

The no-migration standards require that there will be no migration of hazardous constituents from the Injection Zone for as long as the waste remains hazardous. The modeling discussion (Section 7.0) addresses this issue in relationship to migration through geologic strata, and for artificial penetrations that intersect the waste plumes within the operational and 10,000 year timeframes. To satisfy the no-migration standards for these artificial penetrations, a well must be constructed with casing, cement, or mud of sufficient thicknesses and density in the wellbore to allow a demonstration that waste will not migrate up the wellbore and out of the Injection Zone through either injection

pressure induced flow or molecular diffusion. Within the applicable 2-mile radius composite AOR, there are 26 wells (not including the three Ineos wells) which penetrated to at least the top of one of the Ineos Injection Intervals (see Plate 3-1) and are within the operational/10,000 year plumes. Within the 10,000-year plumes outside of the AOR, there are 108 wells that penetrated at least one of the Ineos Injection Intervals.

It has been demonstrated previously in this section that pressure effects are not enough to initiate movement of 9.0 ppg mud out of artificial penetrations due to reservoir injection pressure increases beyond the determined cones of influence, which encompass only the Ineos injection wells. Therefore, no waste movement will occur up any surrounding artificial penetrations due to injection pressure induced flow (advective transport). The effects of molecular diffusion must also be considered if the waste plumes intersect artificial penetrations over the operational/10,000-year time frames. The locations of the low density waste plume boundaries at the end of operations and at 10,000 years are shown on the AOR base map (Plate 3-1) and on Figures 7-17, 7-18, and 7-19.

A calculation has been made to determine the total upward movement over 10,000 years due to molecular diffusion. A conservative value of molecular diffusivity was used to model diffusion through a mud-filled borehole. The results of these calculations (discussed in Section 7.5) indicate that a 4.0×10^{-9} order magnitude reduction in concentration for acrylamide will be achieved over a vertical distance of 317 feet due to molecular diffusion in a mud column. This maximum movement assumes a maximum initial concentration at the top of the correlative Injection Interval and no lateral movement of the plume away from the brine column due to buoyancy differences. In reality the maximum concentrations will only occur at the three petitioned injection wells, since concentrations quickly decrease away from these wells, and are transient, as buoyancy differences will move the waste laterally away from the wellbores.

The closest artificial penetrations to the Ineos wells that penetrate the Injection Interval (Map ID No. 63) which might require that this calculation be performed to show that no-

migration standards are met (in the absence of a cement plug across top of the Injection Zone) is approximately 3,000 feet north of the Ineos injection wells. Map ID No. 63 is a plugged dry hole with surface casing set to 1,622 feet, cement plugs within and across the base of that casing, and 9.5 mud filling the open hole below the casing to the total depth of 5,800 feet. The top of the Injection Zone at this well is at a depth of 4,620 feet, with 720 feet between the top of the shallowest Ineos Injection Interval and zone. This well is within the operational and 10,000-year plumes for all three Injection Intervals, although it penetrates only to the WDW-163 Injection Interval.

If it can be demonstrated that migration will be contained in the Injection Zone through a potentially worst case artificial penetration, then it follows that other wells further away potentially encountering the waste plume over 10,000 years will also satisfy the no-migration standards for artificial penetrations. Map ID No. 63 is the closest well which penetrates the uppermost Injection Interval, as discussed above. This well has approximately 720 feet of vertical distance between the tops of the Injection Interval and Injection Zone, and has the highest modeled concentration of injectate over 10,000 years due to its proximity to the Ineos wells. There is only 317 feet of upward molecular diffusion calculated for acrylamide (which has the greatest concentration reduction factor) in such a worst-case abandoned borehole filled only with mud, when the maximum initial waste concentration is used. This leaves an additional approximately 400 feet between the top of the waste in a worst-case artificial penetration at 10,000 years and the top of the Injection Zone. The no-migration standards are met for this potentially worst-case well, and thus in turn for any others within the operational/10,000-year low-density plume boundaries.

Each of the three Injection Interval's dense waste plumes was modeled for a 200-year post-operational period, as shown on Figures 7-20, 7-21, and 7-22. This time period was run in order to show that no oil or gas production wells potentially completed in the Ineos Injection Interval exist within those plume outlines which could potentially cause waste migration out of the Injection Zone. The heavy plume outlines closely mimics the light

plume end-of-operations plume as shown on Plate 3-1. There is no known hydrocarbon production from the Ineos Injection Intervals within the heavy plume areas, or a 5-mile radius of the Ineos wells. In the dense waste plume scenarios, there is no upward force acting on the waste plumes once they are beyond the cones of influence (maximum of 200 feet for the WDW-165 Injection Interval). As such, the artificial penetrations beyond the cones of influence but within the dense plume boundaries have no potential to serve as conduits for upward movement of hazardous constituents out of the Injection Zone, as the densities of the native brines are lighter to than those of the modeled heavy injectate. Consistent with USEPA guidance, 10,000-year heavy plume modeling is not required since Ineos meets the following criteria:

1. The specific gravity of the dense waste stream is greater or equal to than that of the Injection Intervals formation fluids;
2. The dense waste plume is numerically modeled within the minimum 2-mile radius AOR, and;
3. There are no potential impacts of future oil and gas production wells in the vicinity of the facility.

As is demonstrated in Section 7.5.3, there is only 143 feet of advective transport and upward molecular diffusion to a 4.0×10^{-9} order magnitude waste concentration reduction through the Containment Interval strata. The minimum vertical distance between the top of the shallowest Injection Interval and Injection Zone within the boundaries of the modeled operational/10,000-year plume fronts is approximately 700 feet. Thus the waste front does not reach the top of the Injection Zone in the 10,000-year no-migration time frame.

3.1.2 Defined Area of Review

In accordance with 40 CFR §146.63, a fixed 2-mile radius composite AOR is set around the three petitioned Ineos well locations, as this area exceeds that of the calculated cones of influence. Since WDW-163, WDW-164, WDW-165 are in close proximity to one another, the AOR presented on the maps and figures of this application is a combined AOR using the area within the intersecting arcs of a 2-mile radius drawn from the surface location of each wellbore. In addition to the 2-mile radius composite AOR, a review of

artificial penetrations also includes the area encompassed within the boundaries of the low-density operational/10,000-year modeled waste plumes and high-density 200-year modeled waste plumes.

3.2 Fresh Water Artificial Penetrations

A total of eight (8) freshwater artificial penetrations have been identified within ¼ mile of the Ineos facility property boundary. A search of the water wells within this area was conducted by D-B Associates as part of the annual report for the TCEQ. For water well information within the property boundary and an adjacent ¼ mile radius, researched sources included: 1) Texas Water Development Board (TWDB) maps and records, and 2) TCEQ library reports, bulletins and miscellaneous publications. A tabulation of water wells located within this area is included as Table 3-2. Fresh water artificial penetrations are plotted on Plate 3-2.

3.3 Non-Freshwater Artificial Penetrations

In accordance with 40 CFR §146.64, a search of the artificial penetrations within the Ineos composite AOR was conducted by a records research company (D-B Associates, Austin, TX), updated through February 2006. The following sections describe the protocol used to conduct the artificial penetrations identification, location, and plugging adequacy review for the Ineos composite AOR and plume areas.

3.3.1 Protocol for Non-Freshwater Artificial Penetration Identification and Location

The records researcher utilizes both public and private sources of data to identify non-freshwater artificial penetrations. The following sources were accessed during the research to locate and identify the wells within the AOR and plume areas.

Railroad Commission of Texas

The Railroad Commission of Texas (RRC) is the primary agency in which files are researched for oil and gas well records. The RRC is the state repository for oil and gas well records, as well as the state regulatory authority for the oil and gas industry. As the RRC records for the non-freshwater artificial penetrations within the Ineos AOR were

sufficiently complete and informative, it was unnecessary in most cases to go beyond the following RRC research protocol for well records and information.

Maps

Before the retrieval process can begin, it is necessary to know the operator, lease name, and county in which the well is found. The preceding information is normally found on commercially prepared oil and gas base maps. The Railroad Commission of Texas maintains two types of maps, which are used by the researcher to determine operator, well name, approximate drilling date, and field name. The following two types of maps are on file at the RRC.

County Maps: These maps are produced by commercial firms who obtain the data to build the oil and gas base from "scout tickets" (completion information received from individual oil companies) in the early years and then, in later years, from the base maps, plotting incoming information filed by oil and gas operators. Changes in the status of existing wells are notated, as well as factual material on new wells.

Field Maps: These maps are prepared by RRC personnel from the commercial base maps. "Field maps" are prepared when there is an extremely high well concentration in an area and it is necessary to expand the scale of the area so that wells can be properly identified. All data including survey name, fee name, acreage configuration of tracts of land, operator name, and well location data are taken from the county map and transposed onto the "field map." Once the "field map" is prepared, any wells drilled, deepened, plugged back, or plugged in the area encompassed are spotted on this map.

The researcher utilized both types of maps on file with the RRC as well as other available commercial oil and gas base maps. The information found on these various base maps is used to proceed to the next step of the research process.

Microfiche and Microfilm Records: All records filed with the Railroad Commission of Texas prior to 1973 are found on microfiche and microfilm. Records in some RRC

districts are filmed through 1980. These microfiche and microfilm records are organized in several different systems, such as operator and lease name; district, field, and operator name; or district, field, and lease number. Within the aforementioned filing systems, there are a large number of exceptions to the filing procedures that create additional filing systems within these categories.

The various types of standard film sets are as follows.

Unit Cards: These are microfiche records for wells that had records filed with the RRC prior to 1962. These "units" are filed sequentially by an operator number assigned by the Railroad Commission of Texas at the time the operator filed the required organization report with the agency. The operator number can be referenced in either the "county book" or the "county microfiche." There is a "county book" maintained for each county within the state. Within the "county book", the information is organized alphabetically by lease name, which cross references to the operator name and corresponding operator number. The "county microfiche" are a recent addition to the RRC filing system. The agency took the "county books" and reorganized the leases into alphabetic order and microfilmed the information. Although the "county books" are not organized as neatly as the "county microfiche", they are the original system and are more accurate.

Operator numbers can also be obtained from old copies of organization ledgers maintained by the RRC. These ledgers are in five separate sets that correspond to various time periods from the 1920s to the 1960s. These ledgers list only operator names, addresses, and numbers assigned by the agency and are used as a last resort, since they do not indicate lease names and often list multiple operators with the same name.

Once the operator name is matched to a lease name and an operator number is given, the unit card, if available, is pulled. The lease names are filed alphabetically within each operator number. Since there are exceptions to the filing system, if the desired information is not available or only partially available on the unit card, then the researcher must proceed to the next set of microfilm.

Well Records; Folder Rolls: Duplicate copies of unit cards, which sometimes contain information that was not included in the initial filming of the unit cards, are referenced on the folder rolls. The folder rolls are organized by operator number and folder number, which appear on the unit card jacket. In addition, some folder rolls do not have a folder number given but only an operator number. These rolls are called "add-on rolls" and also contain records not included in the initial filming of the unit cards.

Well Records; Runs 20 to 30 and A to I: These rolls are organized by operator number and by specific periods of years. These rolls encompass a period from 1945 to 1960 and commonly have three to five rolls for a specific year and operator number. When information is not available on the unit cards, these are the next set of film to be researched for records.

Well Records; Major Runs: This is a special set of film that contains only information on records filed by major operators. These rolls are organized by operator and then alphabetically by lease name. It should be noted that there are very few unit cards for major companies and that if any information was filed on a lease or well, it will be found on this set of film. It should also be noted that major operators, even in the early years of the oil business, were very prudent about filing completions and plugs for wells that they operated.

Well Records; Old Warehouse Film: This set of film contains some of the very earliest information filed with the Railroad Commission of Texas and includes oil and gas well records filed from 1919 to 1939. There are only five rolls of this film, with three rolls organized numerically by operator number and two rolls organized alphabetically by operator name.

Well Records; K, L, and M Film: In March 1966, the Railroad Commission of Texas instituted a new filing system; however, before the system could be fully implemented, many well records which were filed during the period of transition were placed onto the

K, L, and M film. The K Run covers portions of records filed from 1963 to 1964; the L Run covers portions of records filed from 1964 to 1965; and the M Run covers portions of records filed from 1965 to March 1966. The K, L, and M film sets are organized by operator number, with leases listed alphabetically within each operator number.

Potential Film: In March of 1966, the RRC filing system was converted to the "potential" filing system, which is currently used today. This film contains records of all wells that produced oil and/or gas and were placed in a designated oil or gas field. This film is organized by Railroad Commission of Texas District, field name, and oil lease number or gas well identification number.

Wildcat and Suspense Film: The wells on this set of film differ in that they were to be drilled in wildcat fields or fields which were not producing at the time the Application to Drill was submitted to the RRC. This film is organized by district, county, and/or American Petroleum Institute (API) number. The API number system has been in effect since April 1966. The numbers are stored within the RRC computer system and noted on all forms filed for the well. The system allows information to be retrieved by computer, showing drilling status, operator, lease name, oil lease number or gas identification number, and field name. This is a very efficient system and allows quick and accurate retrieval of data filed since 1978.

Well Records Files: These are the hard copy files of data not yet placed on microfilm. These files are organized by district, field name, and oil lease number or gas identification number. These files contain the most recent data processed by the Central Records staff of the Railroad Commission of Texas. Inside these folders are references to data that has been placed onto potential film.

Suspense Files: These files contain the most recent information to be filed with the Central Records Department. This is the holding area for information to be placed into existing well record files or to have new oil lease or gas identification files prepared. The information is filed by district and API number. To obtain API numbers assigned to these

records, it is necessary to search "suspense cards" that are filed by district, county, and alphabetically by lease name. Records that have not been placed in suspense files are usually found within the Map Department, where they are held until data is placed on the county oil and gas base maps or on field maps.

The aforementioned records sets are the primary file systems utilized to access records in the Railroad Commission of Texas. It is important to note that in the early years of the oil and gas industry in Texas, this agency was not the enforcement body it is today. Early operators sometimes tended to be less than diligent in filing required information with the Railroad Commission of Texas. This, in combination with the massive amount of data maintained by the agency, provided many opportunities for data gaps to occur, either due to no records being filed or records being misfiled within the agency. In retrieving information from the Railroad Commission of Texas, the researcher often has to examine every file system available in the search for a particular piece of information. After all avenues have been searched, the desired records may not be available in the filing system. This is normally due to operator omission or lost and misfiled records handled by the Railroad Commission of Texas.

Alternate Records Sources

In instances where complete well data are unavailable within the RRC filing system, the researcher then proceeds to various alternatives outside of this agency. These sources are as follows.

Balcones Research Center - University of Texas

The Balcones Research Center maintains a well sample library that contains approximately 750,000 driller's logs. These driller's logs were donated to the University from the 1920s to the early 1960s by various oil and gas operators and private log libraries. The records are organized by county and then alphabetically by operator name. These driller's logs contain well location data, formation record, casing record, initial production potential, and sometimes the plugging information.

This library has proved to be an excellent source in cases where base map information is incorrect. The researcher is able to go into a county and research by survey name to identify wells within an area that may not be on file with the RRC.

Commercial Log Libraries

When required data cannot be found from the two aforementioned sources, the researcher then purchases membership privileges with a commercial library. These libraries maintain extensive electric log collections as well as scout ticket files. Scout tickets often prove very valuable, since full operator name or alternative operator names are listed. These alternative operator names often allow the researcher to re-enter the RRC filing system with previously unknown record leads. Available scout tickets were gathered on all wells in the AOR.

County Deed Records

In some cases the available oil and gas base maps may indicate a well to have been drilled in an area, but the map does not indicate an operator or lease name. It may be necessary to determine the genealogy of the mineral ownership and various lessors on a specific tract of land. By examining deed records on file in the county of interest one is able to ascertain the names of various individuals and/or companies that once owned minerals or drilling rights to a tract of land. These names can be utilized to re-examine the records on file with the various aforementioned public and private information sources.

Scout Tickets

Scout tickets originated as part of the scouting service that oil companies provided for their geological staffs in the earlier periods of the oil industry. Oil scouts for a company originally gathered drilling, completion, and other geologic data on their own company's wells and wrote this information on small summary cards, which were put in the appropriate well files and were available for intracompany use. Since the combined number of wells drilled by other companies were a potential for significantly greater

amounts of data than those drilled by a single company, the oil scouts began the tradition of meeting weekly and exchanging information on their wells as a means of acquiring a better database. If an oil company was drilling a "tight" hole and would not release any information on the well, that company's scout was excluded from the weekly meetings of data exchange. The early scout tickets (1920s to 1940s) were often handwritten, usually on 5-inch by 7-inch cards.

As the number of wells drilled in an area grew and the database expanded, commercial scouting services were formed to keep track of and sell data to the oil companies. From the 1940s through the 1960s, as many as three to five companies competed in an area to provide this service. Today, however, there are usually only one to two companies with scout tickets of wells from a certain geographical area. Petroleum Information Corporation and Dwight's Energy Data are the main companies providing scout ticket data today.

Scout tickets are today called "Completion Cards", as the data is not gathered in the same fashion, as were the original scout tickets. The data gathered for the cards is usually gleaned from public information files at the Railroad Commission of Texas or appropriate regulatory agencies for other states. When a well is drilled and either completed as a producer or is dry and plugged, the operator must file certain forms. The commercial data-gathering company will then use these forms to put together a completion card for publication and sale.

There is certain information that is usually included on all scout tickets or completion cards. This includes well name, location, drilling dates, total depth, elevation of ground surface, casing records, results of well, and completion data if the well was completed. This completion data includes depth of perforations, well test pressures and flow rates, and initial potentials. Additional information which is at times available includes geologic formation boundaries, sidewall and whole core results, drill-stem test results, and mud logging shows.

Not all wells, particularly older ones, will have scout tickets. There is no requirement for certain data to be included, nor is there a standard format that all companies follow in listing the data. Incorrect information is at times printed on the cards. The cards provide a valuable service to the oil industry, but correlating data from other sources is generally required before a major economic decision is made based on information from the cards, such as the drilling of a well to test for hydrocarbons.

3.3.2 Protocol for Determining Non-Freshwater Artificial Penetration Completion or Plugging Status

Records for artificial penetrations identified within the AOR were retrieved and reviewed to determine the actual location and status of each well, i.e., operating or plugged. In Texas, these wells are required by the Railroad Commission of Texas and/or the TCEQ to have surface casings set below the base of fresh water ($< 3,000$ TDS) and cemented to the ground surface. Surface casing provides a primary means of protecting ground waters penetrated by a wellbore. Wells that penetrated the Ineos Injection Zone were further reviewed. Casing and cementing data of the operating wells were reviewed to determine if sufficient cement is in place to adequately prevent upward migration of fluids. Plugged wells were reviewed to determine the adequacy of mud or cement plugs.

3.3.3 Location Map and Tabulation of Non-Freshwater Artificial Penetrations

A map showing the location of non-freshwater artificial penetrations within the Ineos composite AOR and low-density operational/10,000-year plumes is included as Plate 3-1 (Non-Freshwater Artificial Penetrations Location Map) of this application. A tabulation of non-freshwater artificial penetrations that penetrate the Injection Zone within the Ineos 2-mile radius composite AOR is included as Table 3-3. A tabulation of the additional non-freshwater artificial penetrations that penetrate the Injection Zone within the Ineos low-density operational/10,000-year plumes outside of the composite AOR is included as Table 3-4.